CTD Chain Deployment in the Korean Experiment

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LONG-TERM GOALS

Establish quantitative relationships between acoustic signal behavior and high resolution water column dynamic features, such as internal waves and stabilized buoyant density intrusions.

OBJECTIVES

Participate in a joint project between the Republic of Korea, The US Navy Naval Research Laboratory (NRL), The Applied Physics Laboratory, University of Washington and The Applied Research Laboratory, Pennsylvania State University. The purpose of the joint program is to collect sufficient environmental data in the East China Sea to interpret the behavior of a Horizontal Linear Array that provided acoustic array data for low frequency signals over a two week period in 2008.

APPROACH

A Conductivity, Temperature and Pressure (Depth) (CTD) sensor array was towed for two days over the same area that the acoustic signals traveled, and during the time when the acoustic array was collecting data. That data base and ancillary environmental information available from Korea is the basis for the theses of two graduate students enrolled in Pennsylvania State University's Graduate Program in Acoustics.

WORK COMPLETED

Analysis of the data has been completed. Figure 1 shows both the experimental site and Internal Wave (IW) activity shortly before the CTD chain tows. It also provides details of specific IWs encountered during the tow period. Figures 2 and 3 illustrate the range-depth dependence of sea water density and sound speed respectively for a specific track (#52) indicated in Figure 1.

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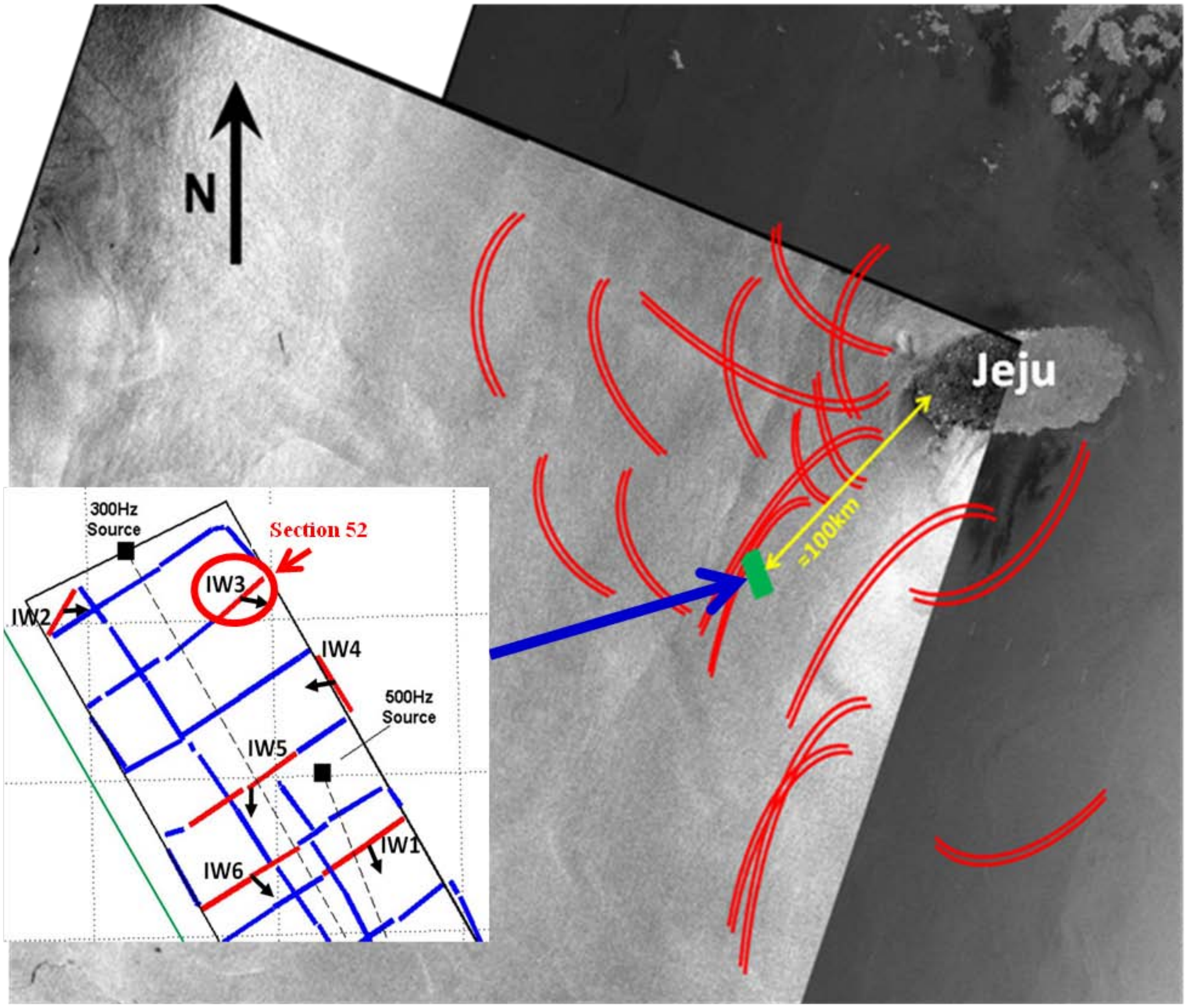

Figure 1. Internal Wave (IW) activity in the experimental site vicinity. The inset illustrates 6 specific measured IW vectors and their locations relative to acoustic source-receiver tracks.

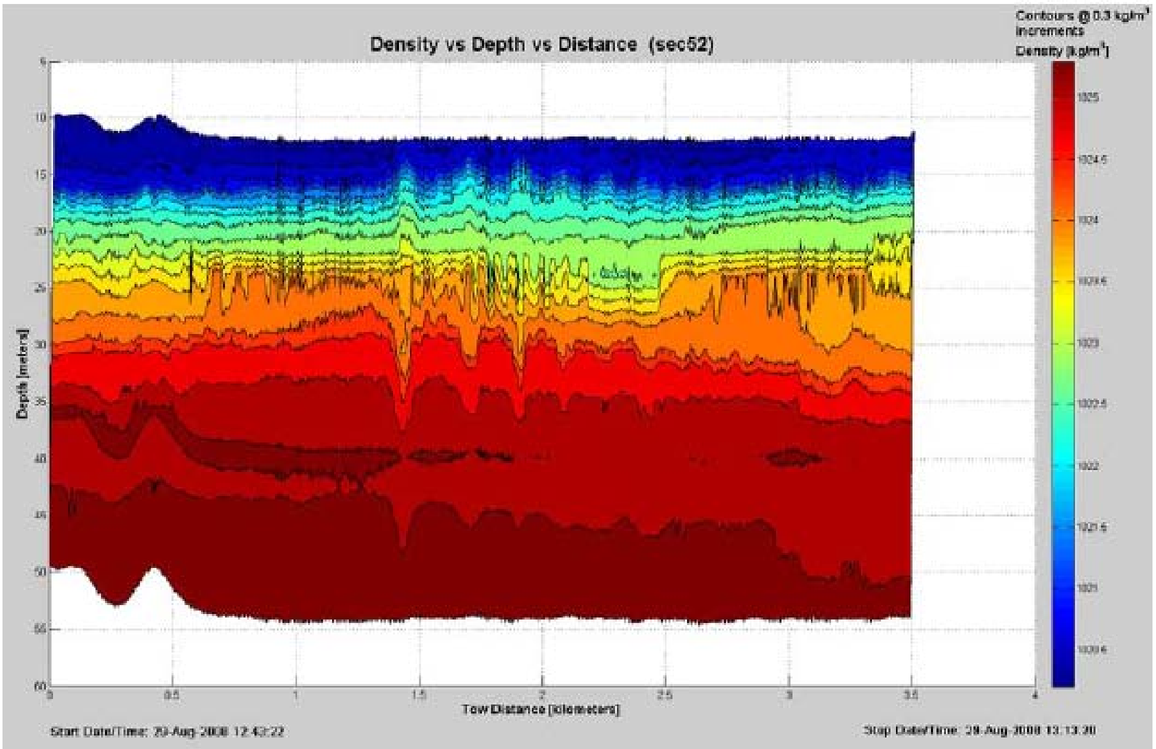

Figure 2. CTD tow section 52. Seawater Density. Depth 0-80 m; Range 0-3.5 km

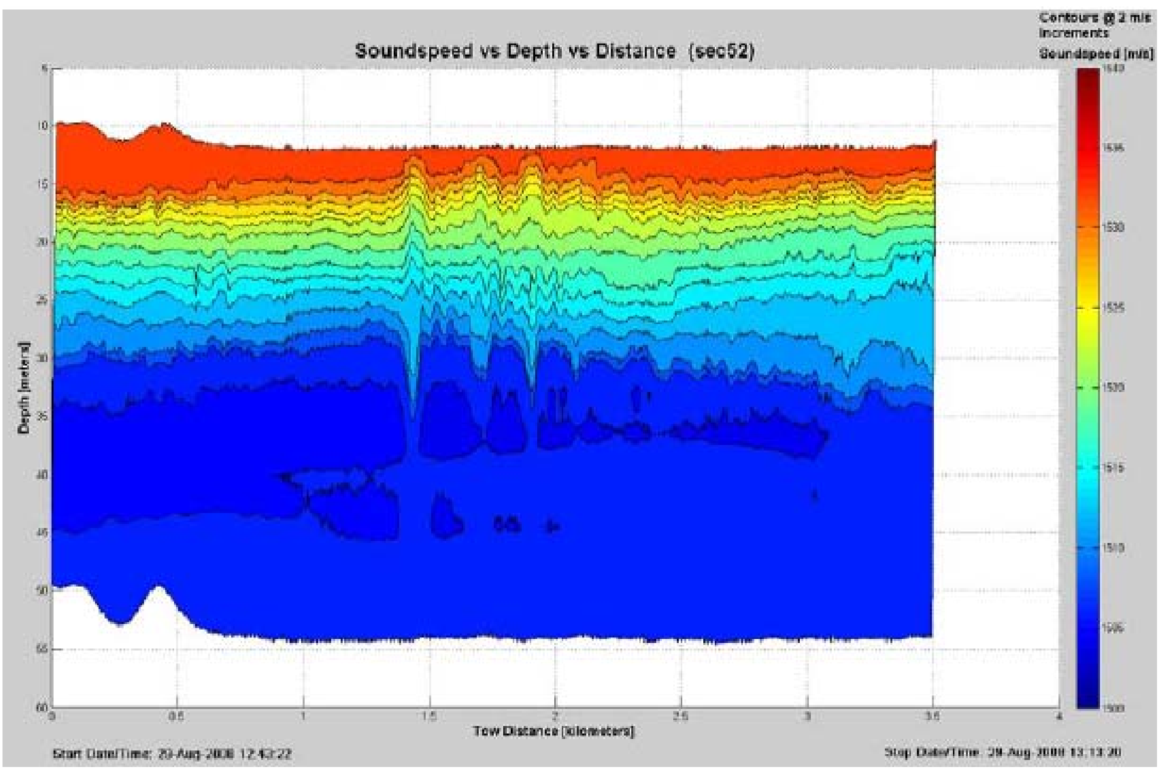

Figure 3. CTD tow section 52. Soundspeed. Depth 0-80 m; Range 0-3.5 km

RESULTS

Two major avenues of research were pursued. The first was examination of the adjoint method for its usefulness in linking water column variability to acoustic signal behavior. Adjoint methods, while relatively new in the field of underwater acoustics, have been applied in many different disciplines with positive results. The fields of aerospace engineering, meterology and seismology have all used adjoint methods to solve inverse problems within their disciplines. Since the method works almost identically in each situation, studying literature from other disciplines has been quite helpful.

The adjoint modeling process begins with a baseline (historical or measured) sound speed profile driving a forward model, generating a model prediction. The forward model (e.g., Finite Difference PE) can be that propagation model best suited to the extant environment. Next, the prediction from the baseline profile at the last range step R is compared to the acoustic measurements using a cost function that quantifies the data – prediction misfit. The adjoint model, which back propagates the data – prediction misfit back to the field points where the sound speed profiles need to be adjusted, is next derived from a linearized perturbed model (LPM). The LPM is a forward model that estimates pressure field differences, and is derived from (for this research) FD PE models using perturbative methods. The back propagation matrices from the adjoint model are then inserted into the gradients of the cost function to solve for the sound speed profiles that minimize the data-prediction misfit. The iterative process then continues by using the newly – estimated baseline profile to form a new predicted pressure field.

The second research direction focused on an attempt to extract a linkage between the periodicity observed in the IW structure and signal variation of recorded acoustic data. Since the IW has its own periodic behavior, that periodicity should be visible in the time behavior of the received acoustic signal that has traversed the region where the IW is located. That is the premise for the analysis. The procedure is to model the IW, select a geometry of interaction between the acoustic path and the internal wave path and calculate the modeled, received acoustic signal using the RAM PE of Collins[(1)]. This calculation is done as a function of time, accounting for the passage of the IW across the acoustic path. This modeled acoustic signal is then examined in frequency space, looking for the harmonics associated with internal wave behavior. This resulted in peaks in the frequency range associated with IW activity. When the same analysis is performed on recorded acoustic data, strong peaks are also observed in the expected frequency range, but as expected, the frequency display is much more cluttered than the idealized case. The internal wave is modeled as soliton-like disturbance between two constant density layers.

Figure 4 is an averaged spectral content of the acoustic signal due to a modeled internal wave passage across the path between source and receiver.

$$HV_{TL} = \left| FFT\{\mathrm{TL}\} \right|^2$$

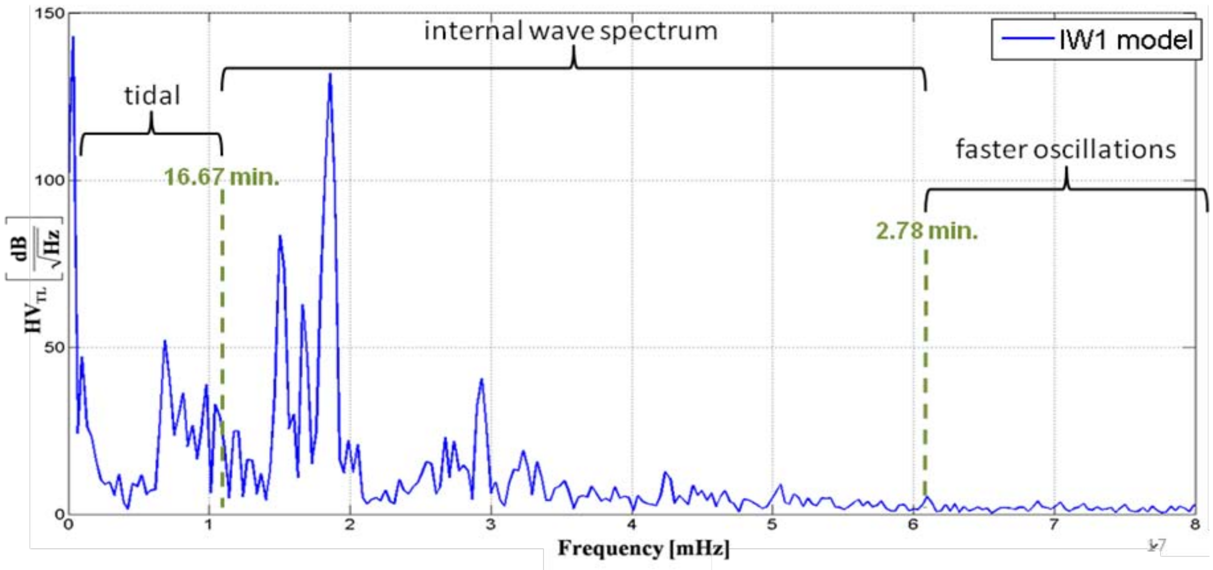

Figure 4. Harmonic Variation Analysis of modeled signal variation with time

Figure 5 shows the time dependent spectral behavior of of the recorded acoustic data, during the passage time of a specific IW (the one modeled in Figure 4), captured during the CTD tows and it clearly has a similar spectral shape as the modeled acoustic field.

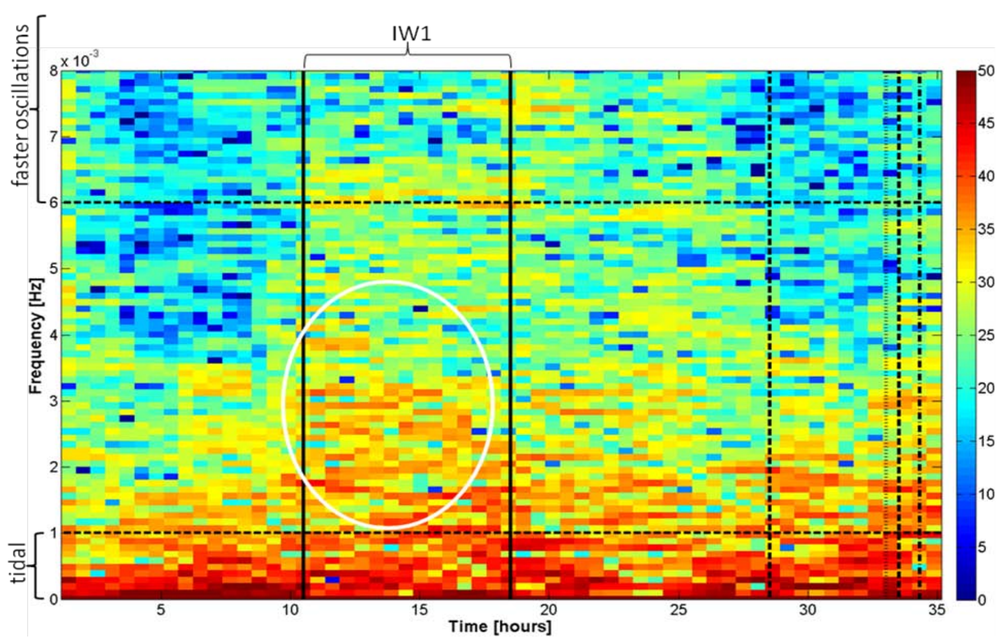

Figure 5. TL Data Analysis

One thesis was completed [2], the student has graduated and is currently deployed on the USS SAMPSON in the Pacific. The second thesis will be completed just after the fiscal year has ended. Three papers were presented, two at the Acoustical Society of America's Spring Meeting[3] [4], and one at the European Conference on Underwater Acoustics (ECUA) in Istanbul, Turkey[5].

IMPACT/APPLICATIONS

The CTD system is capable of high resolution, excellent areal coverage of water column dynamics and the consequent data base, when combined with coincident acoustic recordings, will provide both temporal and spatial understanding of acoustic signal behavior.

TRANSITIONS

None

RELATED PROJECTS

None

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PUBLICATIONS

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